Forest Health Protection
Pacific Southwest Region

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To: Ann Carlson, Forest Supervisor, Mendocino National Forest

Subject: Chico Seed Orchard

At the request of Joe Sherlock (Regional Silviculturist) and Chuck Frank (Zone Geneticist) a site visit was made to the Chico Seed Orchard on July 18, 2018. The objectives were to assess the current conditions and discuss control methods for seed and cone insects. Joe Sherlock, Lisa Crane, Charles Frank, Andrew Mishler (Mendocino NF), and Cynthia Snyder (FHP) attended.

Background

The 209-acre Chico Seed Orchard (CSO), formerly Chico Genetic Resource and Conservation Center (GRCC), was first developed in 1904 and consigned to the Agricultural Research Service of the US Department of Agriculture for plant breeding research and plant introduction from all over the world. It is well known for being the first introduction of kiwi and pistachio to the US. The facility was acquired by the US Forest Service in 1974 when the program was changed to develop and produce genetically improved plant material for reforestation in the Pacific Southwest Region. Currently, the facility produces genetically improved conifer seeds for reforestation and restoration (primarily ponderosa pine and Douglas-fir) and serves as a resource for research in plant genetics and forest health issues including tree disease resistance.

In 2009, the integrated pest management (IPM) plan was revised for the GRCC to provide guidance for controlling pests at tolerable levels by strategic and planned use of a variety of preventative, suppressive, and regulatory methods consistent with seed orchard management goals. One of the pests targeted by the IPM plan was coneworms of the genus *Dioryctria* (Lepidoptera: Pyralidae), specifically on Douglas-fir and ponderosa pine. *Dioryctria* infestations have been a continuing problem at the CSO often drastically reducing viable seed production.

Important considerations – the insect

Coneworms are destructive pests of conifers across North America feeding on a variety of host tissues including cones, flowers, foliage, and cambium depending on species (Whitehouse et al. 2011). Roe et al. (2006) trapped four species of *Dioryctria* at the CSO using a combination of pheromone and light traps, two: *D. abietivorella* and *D. auranticella*, feed on the interior of infested cones consuming cone material and seeds.

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The fir coneworm, *D. abietivorella*, life history is variable and not well known. It is reported as having one and a partial second generation per year in Douglas-fir cones and a single generation per year in ponderosa pine cones in California (Furniss and Carolin 1977), or a single full generation per year composed of two broods in terms of adult emergence (Hedlin et al. 1981). Eggs are laid soon after emergence and larvae feed inside the cones June-September. Some larvae pupate in cocoons on the ground in July-September and adults emerge shortly after to lay eggs, which overwinter. Others overwinter in cocoons as prepupae, which pupate in March-April and emerge as adults in May-June (Hedlin et al. 1981).

Flight of the male is in response to the female pheromones and begins approximately two hours after sunset, peaks about four hours after sunset, and ends one hour after dawn (Whitehouse et al 2011). Oviposition typically begins the night following mating and continues for about two weeks. Eggs are laid on limbs or cone bracts. From oviposition through five larval instars takes about 30 days at which time the larvae exit the cone and pupate in a cocoon either on the side of the cone or in the duff.

Pine coneworm, *D. auranticella*, are typically univoltine with peak adult flight in midsummer (Whitehouse et al 2011). Males emerge two or three days before females. Larvae feed on staminate flowers in early spring and disperse to second year cones later in the season where they complete development, pupate and eclose after fifteen days.

Dioryctria species exhibit polyandrous mating patterns in seed orchards with females of *D. abietivorella* mating up to eight times and other species two – three times. As with other moths, mate finding is mediated by female pheromones. Pheromone components for these two species has been determined (Millar et al. 2005, Whitehouse et al. 2011). It is likely that the females are attracted by host volatiles at the upper canopy where there is a denser congregation of cones and males are attracted to the females. Whitehouse et al. (2011) noted that most *Dioryctria* species exhibit protandry, change from male to female, on a seasonal basis but did not provide insight to the seasonality or effect on populations.

Orchards are managed as monocultures providing an abundant and consistent amount of seed. Larval feeding causes direct and indirect damage to cone and seed production. Larval feeding results in smaller cones with fewer viable seeds and may provide entry points for pathogens. Diplodia tip blight, *Sphaeropsis sapinea*, incidence may be related to cone damage by *Dioryctria*.

Important considerations – IPM

Integrated pest management should include aspects of:

- cultural control – fertilization, irrigation, thinning, ground cover maintenance, etc.,
- manual control – “clean picking” or picking all cones regardless of signs of infestation to remove pests from the orchard,
- biological control – use or encouragement of natural enemies, and
- chemical control – use of registered pesticides.

The current IPM plan mentions only the use of Esfenvalerate (Asana XL™), a synthetic pyrethroid, for control of insects. Updates to include other insecticides may require an update to the current DEIS or letter to the file for insecticides with similar levels of risk.

Observations

Currently the CSO uses ground-based high-pressure applications of Asana XL™. The pesticide is sprayed at night four times each season. Walking through the seed orchard, it is evident that the grafted trees in many of the established orchards are getting too tall for the current method of delivery to effectively reach the upper crown with the current pesticide. This can be tested using pesticide spray cards. Many of the rows have crowns that are touching and starting to intertwine making pesticide application to the mid to upper crown difficult. Final roguing has been done in these clones and it may be time to start considering replacement. All orchards are spaced in a five meter by five meter (16 ft by 16 ft) hexagonal pattern:

DF 1 orchard is 11.1 acres and contains 524 trees = 47.2 trees/ac
DF 3 orchard is 9.1 acres and contains 460 trees = 50.5 trees/ac
DF 4/6 orchard is 11.3 acres and contains 755 trees = 66.8 trees/ac
DF 5/8/9 orchard is 14.4 acres and contains 1090 trees – 75.6 trees/ac
PP 5TR orchard is 8.3 acres and contains 435 trees = 52.4 trees/ac
PP 2 orchard is 14.8 acres and contains 558 trees = 37.7 trees/ac
PP 3 orchard is 14.7 acres and contains 604 trees = 41 tree/ac.

The CSO usually uses a degree-day model for timing insecticide applications based on the one developed to control *D. amatella* in loblolly pine seed orchards in the southeastern US (Hanula et al. 2002). This may not provide the best results, however, no other decision-making models for management of seed-feeding *Dioryctria* have been published to date. The CSO based the timing of insecticide used in 2018 on the posture of the cones as described on the pesticide label. This produced comparable results to the model used previously.

It was noted that when cones are picked, they are not clean-picked meaning all cones removed regardless of signs of infestation. Cones should be clean picked to remove larvae that would otherwise overwinter in the orchard. This would require extra effort and associated cost.

Constraints exist for the use of alternative synthetic pesticides. A local church has built a school next to the CSO and there are beekeepers in the neighborhood. The CSO is centered along Comanche Creek in Chico and has become a highly used recreation area open to the public. Much of the staff time is used to clean up after visitors and provide information about the history and operation of the center and the many exotic tree species lining the creekside path. Proximity to the creek and school limits use of many synthetic pesticides, such as carbaryl, used in other regions to control coneworms.

Effective IPM starts with knowing the species of *Dioryctria* present in the orchard. Roe et al. (2006) noted four species of *Dioryctria* in the CSO, but also provided information that *D. abietivorella* is likely the most common in Douglas fir and may also be co-occurring with *D. auranticella* in ponderosa pine. Monitoring through pheromone

trapping can provide information about any changes in species and emergence times. This monitor trapping is also used to ensure proper timing of treatments. Timing is critical because insecticides usually target early instar larvae before they become established in the cones.

Discussion

Integrated pest management in the seed orchard should include chemical, cultural, manual, and biological controls. These include maintaining the fertilization and irrigation of the clones as well as thinning to reduce competitive stress among the trees. Thinning at this time would provide more adequate space to get chemical controls to the upper crowns where the cone crops are heaviest. Manual control in IPM may also include clean picking the cones regardless of signs of infestation to remove the developing larvae from the orchard. Proper IPM includes monitoring to determine the most effective time to use pesticides and determine if pesticide use is effective. Chemical control is used annually at CSO and it is recommended that alternate chemical pesticides or pesticides with alternative chemistries are used to reduce the risk of resistance.

Action thresholds based upon monitoring results are typically used to make decisions in integrated pest management protocols. Without the development of quantitative methods to monitor for eggs, larvae, or adults, action thresholds cannot be adequately devised for cone-feeding *Dioryctria* species. Currently, pesticide applications are typically timed based on a degree-day model that was developed for *D. amatella*, based on accumulations above a threshold temperature of 11 °C initiated with collection of five male moths in pheromone traps (Hanula et al., 2002). No other decision-making model for management of seed-feeding *Dioryctria* has been published to date.

Broadcast sprays of contact insecticides are the most commonly used insecticide application technique against a variety of *Dioryctria* species. Currently the CSO uses ground-based high-pressure applications of fenvalerate (Asana XL™). The pesticide is sprayed at night four times each season. This approach may lead to pesticide resistance in the insect. A better approach would be to use alternating products for each spray in a season or to alternate chemistries (chemical classes). However, proximity to the creek and school, as well as other neighbors, limits certain chemicals that may be highly effective in other regions from being used at the site.

Possible biopesticides were discussed. Pathogenic microorganisms infect several *Dioryctria* species. Mihelcic et al. (2003) found that the fungus *Beauveria bassiana* infected 0.4% of sampled *D. amatella*, larvae. In laboratory trials, *B. bassiana* was virulent against all larval stages. Although natural infection rates of *B. bassiana* are often low, a sprayable product is commercially available (Laverlam International Corporation, Butte, Montana USA) and has potential for development as a biopesticide in this system.

The commercially available biopesticide, *Bacillus thuringiensis* subsp. *kurstaki* (Btk), has been tested against *D. abietivorella* and Trudel et al. (1997) found that all developmental instars are highly and equally susceptible to Btk. McLeod et al. (1984) field-tested Btk sprays in Oklahoma on loblolly pine and found that Btk application one week after *D. amatella* were first caught in pheromone traps increased cone survival by approximately 18% and seed set per cone by 48%. However, no significant protection from *D. amatella* occurred if Btk was applied two weeks after first trap catch, suggesting that application

timing is critical to the success of Btk (McLeod et al., 1984). The efficacy of Btk has been most thoroughly tested against *D. abietella* in Norway spruce seed orchards in Sweden where three applications, starting within one week of the onset of adult flight, were seen to reduce the incidence of infested cones by 65% (Weslien, 1999). Further studies determined that although Btk loses 80% of its efficacy within the first 14 days of application, spraying when flowers were open for pollination ensured that the Btk reaches the interior of the cones where larvae feed thereby getting more insecticide to the target organism (Rosenberg and Weslien 2005).

There was also discussions about spinosyn active ingredient pesticides. These newer biopesticides are fermentation derivatives of *Saccharopolyspora spinosa*, an actinomycete bacterium. They are considered reduced risk pesticides by EPA and used in southern seed orchards as alternatives to pyrethroids in IPM programs.

The possible use of systemic insecticides was discussed. Advantages of systemic insecticides, which can translocate into cones and kill seed-feeding insects, include reduced non-target mortality and elimination of problems associated with drift and inconsistent deposition. The efficacy of injection of loblolly pine stems with emamectin benzoate (EB) was tested in Texas (Grosman et al., 2002). A single application of EB reduced damage from *Dioryctria* species by 94 - 97% over a two-year period. Further studies continued to show reduced damage to cones by coneworms with protection equal with spring or fall treatments and added protection against other insect pests (Cook et al. 2013[a], Cook et al. 2013[b]). Systemics are costly and labor intensive. It was discussed that they might be an option for the highest valued clones or used as a buffer along orchard edges to allow more chemical options within the buffers.

Another topic of discussion was the possibility of using mating disruption or “attract and kill” technologies. These are typically deployed for the management of shoot boring moths, *Eucosma* and *Rhyacionia* spp., in pine plantations (Daterman et al. 2001). Attract and kill technology very selectively removes male moths of the target species from the ecosystem with negligible impact on non-target organisms. Baits combine the selectivity of pheromone (as with mating disruption) with the rapid toxicity of insecticides. However, although mating disruption has been shown to reduce male moth catches in both the US and Sweden (DeBarr et al. 2000, and Svensson et al. 2018) neither technology has reduced larval abundance or damage.

Conclusions

Conifer seed orchards, like CSO, produce high-quality seed from selected genotypes of important tree species for the reforestation and restoration of forest lands. The genetically improved seed has such a high economic value that there is very little tolerance of damage. It is evident from the walk through that many of the ponderosa pine and Douglas fir orchards have grown too tall and too dense for adequate pesticide coverage especially to the upper crown where the cone load is heaviest. It would be my recommendation that the CSO to do a spray card test to determine how much chemical is getting to the upper tree crowns. It may be time to consider removing certain rows and planting new grafts to start providing for future needs of the seed orchard and thinning where new grafts are not feasible. Fewer trees may increase the effectiveness of pesticide used and provide extra time required to clean-pick all cones thereby removing all larvae from the orchard.

Pesticide resistance can become a problem when the same chemical is used over and over to control a particular pest. The goal of successful resistance management is to reduce populations of pests, whether they are resistant or susceptible to pesticides. The general recommendation when using pesticides is to alternate pesticides of different chemistry and modes of action. This recommendation is based on the theory that the likelihood of a population developing resistance to two or more pesticides, each from a different chemical group with different modes of action, is significantly less than the likelihood that a population could develop resistance to only one of the pesticides. Therefore, individuals in the pest population resistant to one of the pesticides would be killed upon exposure to the (different) partner pesticide.

There are alternatives to the single chemical currently being used at CSO. There are opportunities to add to the tools through a letter to the file or an update to the current EIS. There are opportunities to bring in researchers from the Pacific Southwest Research Station to perform field trials of newer biopesticides or systemics. I suggest that it is time to schedule a meeting with Seed Orchard Managers, Regional Genetists, Silviculturists, Entomologists, Pathologists, and Pesticide Coordinators to discuss the current and future needs and direction of the seed orchard and revise the current IPM plan to incorporate new tools for cone and seed protection.

If you have any questions regarding this report and/or need additional information, please contact Cynthia Snyder at 530-226-2437 or Pete Angwin at 530-226-2436.

/s/ Cynthia Snyder

CC: Joe Sherlock, Chuck Frank, Dave Bakke, Lisa Crane, Andrew Mishler, Chris Losi, Sheri Smith, Phil Cannon, Sherry Hazlehurst, Chris Fischer, and Pete Angwin

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